NTIS HC $3.25

NASA TECHNICAL TRANSLATION

NASA TT F-14,660

DISCUSSION AND PLANNING OF A SYSTEM FOR A TELEVISION TRANSMITTING SATELLITE

H. Billig

Translation of: "Systemauslegung und Planung fuer einen Ferhsehrundfunksatelliten," Gesellschaft fuer Weltraumforschung mbH, Porz-Wahn, West Germany, Report No. 72-051, October 1972, 18 pages.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D. C. 20546 JANUARY 1973

STANDARD TITLE PAGE

1. Report No.	14,660
2. Government Accession No.	
3. Recipient's Catalog No.	
4. Title and Subtitle	DISCUSSION AND PLANNING OF A SYSTEM FOR A TELEVISION TRANSMITTING SATELLITE
5. Report Date	Jan. 19, 1973
6. Performing Organization Code	
7. Author(s)	H. Billig
8. Performing Organization Report No.	
9. Performing Organization Name and Address	SCITRAN Box 5456 Santa Barbara, CA 93108
10. Work Unit No.	
11. Contract or Grant No.	NASw-2483
12. Sponsoring Agency Name and Address	National Aeronautics and Space Administration Washington, D.C. 20546
13. Type of Report and Period Covered	Translation
14. Sponsoring Agency Code	
15. Supplementary Notes	Translation of: "Systemauslegung und Planung fuer einen Ferhsehrundfunksatelliten," Gesellschaft fuer Weltraumforschung mbH, Porz-Wahn, West Germany, Report No. 72-051, October 1972, 18 pages.

16. Abstract

The requirements of the Federal Post Office for more television programs in the forseeable future can be met by a satellite television system. This is particularly attractive in combination with local cable systems. Although many problems are yet to be solved, an operational satellite system could be completed by about 1980.

17. Key Words (Selected by Author(s))	
18. Distribution Statement	Unclassified - Unlimited
19. Security Classif. (of this report)	Unclassified
20. Security Classif. (of this page)	Unclassified
21. No. of Pages	19
22. Price	3.75

DISCUSSION AND PLANNING OF A SYSTEM FOR A TELEVISION TRANSMITTING SATELLITE

H. Billig

ABSTRACT. The requirements of the Federal Post Office for more television programs in the forseeable future can be met by a satellite television system. This is particularly attractive in combination with local cable systems. Although many problems are yet to be solved, an operational satellite system could be completed by about 1980.

/1*

1. Introduction

The Society for Space Research, under contract from the Federal Ministry for Education and Science, has had conceptual studies made by the industry and intends to let short study contracts for feasibility analyses of the recommended concepts.

The communications requirements established by the German Federal Post Office and the television transmission system are explained, and important results of the first studies, as well as problems in system design and project planning, are presented.

*Numbers in the margin indicate pagination in the original foreign text.

2. Requirements

In planning for the forseeable future, the authorities responsible for television in the Federal Republic of Germany proceed from the assumption that there will be an additional requirement for television programs. They have worked out the following planning model:

- Number of additional video channels:	3 - 5
- Audio channels:	2 per video channel
- Television standard	G-Pal
- Area Covered:	1. Federal Republic of Germany 2. German-language areas of Europe
- Picture quality:	48 dB (Evaluation factor 16.3 dB) 99% of the time
- Receivers:	Standard commercial equipment
- Programming time:	To 1:00 AM
- Time of beginning operation:	After 1980

Various transmission systems offer themselves for the solution of such a problem:

- further development of the terrestrial television network
- cable system
- television transmitting satellite
- mixed systems

/2

Choice of a broadcasting system depends, on one hand, on its reliability, flexibility and economy; and on the other hand, on the availability of appropriate frequencies and on international agreements in this respect.

At this point we will not go more deeply into these considerations about the possible broadcasting systems. The following discussions, therefore, refer only to a television transmitting satellite, for which the Post Office has established the following limiting requirements:

- frequency upward:	11.7 - 12.5 GHz
- frequency downward:	14 - 14.5 GHz (10.95 - 11.2 or 12.5 - 12.75 GHz)
- video modulation	FM
- audio modulation	FM on a subcarrier, or PCM in the video signal
- RF bandwidth	ca. 30 MHz
- atmospheric attenuation (gas, clouds, rain):	1 dB (99% of the time) 3 dB (99.9% of the time)
- receivers:	Individual receiver: G/T = 4 dB/°K Community reception: C/N about 3 - 8 dB higher than for individual reception.

Figure 1 shows the corresponding receiving area as seen from the satellite. The inner ellipse circumscribes the region of guaranteed reception. Because of the expected attitude error of about 0.1°, there is an antenna diagram projected on the Earth corresponding to the large ellipse with a drop of 4.3 dB with respect to the center (maximum field efficiency).

/3

The image quality defined in the planning model for the television receiver is plotted in Figure 2 as a function of the signal-to-noise separation evaluated in the luminance channel. This presentation clearly shows the extent to which the satellite power must be increased in order to improve the picture quality.

Now, from the planning model and the limiting requirements for the television transmitting satellite, there arise the following particularly critical requirements for the over-all television transmitting satellite:

- new frequency range (12 - 14 GHz)
- very high amplification and transmitting power (ca. 120 dB, ca. 600 W per channel)
- high directional accuracy for the antenna radiation lobe (roll and pitch axes 0.1°, position 0.1°)
- receiving systems with favorable costs.

These requirements determine the design of the total system. They will now be investigated in relation to their effects on the most important systems or subsystems involved.

3. Over-all television transmitting satellite system

The total system for the television transmitting satellite is divided up as follows:

- Mission analysis
  - o Communications technology system
  - o Mission profile
  - o Booster system and apogee motor
- Satellite and payload system
  - o Antennas
  - o Transponder
  - o HF wiring
  - o Orbit and attitude control
  - o Power supply
  - o TM/TC
  - o Heat balance
  - o Test planning /4
  - o Product assurance
  - o Home receiving systems
  - o Ground transmitter sites
  - o Ground operating system

The communications technology system is shown in Figure 3. The attenuations of the television signal are indicated crudely and the most important system data are entered.

As the antennas must be continuously directed toward the Earth and the solar cells must be as nearly perpendicular to the solar radiation as possible, these two subsystems must be arranged so that they can be rotated with respect to each other. From this there arise two basic satellite concepts which are sketched in Figure 4.

The first is characterized by an axis of rotation between the solar generator and the satellite body. The specific technological problems are in the transmission of the power across the axis of rotation:

Power Transmission Components

Requirements:
- long lifetime
- low rate of rotation
- high power level

Possible solutions:
- slip rings
- rotary transformer
- liquid metal slip rings
- roll of cable (requires additional maneuvering)
- elastic contact rollers

/5

Problems:
- insufficient space experience with the prescribed requirements.

In the second basic satellite concept the antennas are attached to the satellite body so that they can be rotated. Here the problem is represented by transmission of RF power in both directions through a rotary antenna coupling.

Rotary antenna coupling

Requirement:
- low-loss transmission of the transmitted signal between the Earth-oriented antenna and the sun-oriented satellite body.
- decoupling of the transmitted and received signal and signal transmission

Possible solution:
- integrated disk and waveguide rotary coupling

Problems:
- insufficient space experience

4. Satellite subsystems

Both the satellite concepts described above present identical or similar problems to the other subsystems. These requirements, as well as possible routes to solutions and major problems, are tabulated below. /6

Transmitting antenna

Requirements:
- high antenna efficiency
- small minor lobe
- low thermal and dynamic deformation
- if necessary, equipment for fine direction of the beam

Possible solutions:
- parabolic antenna
  (0.64° x 1.15° elliptical major lobe)
- mechanical or electrical control of the antenna pattern

Problems:
- maintenance of the prescribed shape
- fine direction of the beam

Transponder

Requirements:

- transmitter tube power of 500 - 800 W RF per video channel
- decoupling of the receiving and transmitting paths and of the individual channels
- maintenance of requirements for electromagnetic interference

Possible solutions:

- single or double frequency conversion
- use of traveling wave tubes or klystrons

Problems:

- transmitter tube efficiency
- control of the high supply voltages at high power
- attainment of decoupling

/7

Orbit and Attitude Control

Requirements:

- maneuver (transfer and acquisition phase)
- mission operation
  - o positional accuracy: ca. $\pm$ 0.1°
  - o attitude accuracy: roll and pitch axis: ca. $\pm$ 0.1°
- reacquisition maneuver

Possible solutions:

- attitude measurement: rate gyro, solar sensor, infrared sensor, star sensor, RF sensor
- attitude control
  - o with thrust system (hot gas, cold gas, electric drive)
  - o with supplementary flywheels
  - o with supplementary antenna fine control (electronic or mechanical)
- orbit control
  - o separate system (hot gas, electric drive)
  - o combined with attitude control

Problems:

- high directional accuracy for the antenna lobe
- large satellite mass and dimensions
- low satellite rigidity
- long lifetime

Power supply

Requirements:

- production of the power necessary for the transfer and acquisition phase
- production of about 5 KW until the end of the satellite lifetime
- production of the necessary power during the shadow phases
- power conditioning and distribution

Possible solutions:

- solar generator (which can be unrolled, unfolded, or spread out)
- control: shunt, input control, etc.
- type of power: AC or DC
- main bus or buses with different voltages

Problems:

- solar generator
- high-power components
- maintenance of electromagnetic interference requirements

Heat Balance

Requirements:

- maintenance of the thermal operating limits of the satellite under the following conditions:
  - o change in power generation
  - o change in external heat stress
  - o fluctuating power consumption

Possible solutions:

- passive heat regulation (coatings, SSM, insulation, radiators, etc.)
- active heat regulation (shutters, heat pipes, cooling circuits, etc.)

Problems:

- cooling of the power tube, the output multiplexer, the power generation system, and the power distribution system
  - o power tube (very large amount of heat, possibly high temperatures)
  - o output multiplexer and power distribution system (large amount of heat, low temperatures, smaller temperature range)

/9

The mass of the satellite is greatly affected by the technical quality of the various components (e. g., the efficiency of the power tube). But, quite separately, the mass depends on some yet undecided planning data such as the number of channels, the picture quality, and the reception area. These relations are shown in Figure 5.

5. Home receiving system

Of the remaining systems, only the home receiving system will be considered here because of its particular importance.

Requirements:

- highest possible quality factor
- conversion of frequency-modulated 12 GHz received signal to the existing television standard
- favorable cost for the system

Possible solutions (Figure 6):

- individual system, consisting of parabolic antenna (diameter up to 0.8 m), converter, amplifier and modulation converter.
- cable system with the same components, but correspondingly more expensive because of the higher demands on them.

Problems:

- economy of the system
- directional accuracy of the antenna
- system degradation

6. Project planning

Planning and construction of an operational satellite system for television broadcasting include technological, temporal, and financial risks which cannot yet be surveyed completely. In order to make these risks calculable, phase-wise project planning is applied for the system (Figure 7). / 10

Here the course of the project is organized so that the knowledge of all aspects of the project increases from phase to phase. Each phase is in itself a complete plan with its own objectives and its own program plan. This ensures that costly developments are started only if their necessity and achievability have been sufficiently demonstrated in the preceding phase; that is, when the financial and technical risk for the customer has been reduced to a minimum.

At the end of development phase C, when only 5 - 8% of the total resources are spent, all aspects of the project will be known well enough so that a decision can be made on the development and construction of the equipment and on test operations, that is, on application of the total resources.

The first satellite can be launched after about 7 years, with the start of operation 15 months later.

In parallel with the phased project performance, preliminary developments will be undertaken with the goal, on one hand, of working out the technical bases for decisions on conclusion of the individual phases, and, on the other hand, of solving critical technical problem areas in good time.

A further decrease in the risk and better optimization of the operational system could be achieved by use of a test satellite (Figure 8). This would be characterized by a decrease in the number of channels and of the picture quality, lifetime, and reliability, as well as by redundance of critical components. With use of a test satellite, to be sure, the first operational satellite could only be launched after some 10 years.

/11

7. Costs

Determination of the costs for the operational system for television broadcasting by satellites is an extraordinarily complex problem. Its findings must still be very uncertain, particularly because important requirements for the customer, such as the number of programs to be transmitted, the area to be covered, video and audio quality, and the system reliability required, are not yet clearly established. Only after knowing these requirements can the operational system be optimized with respect to its parameters, and a detailed cost analysis performed (this work is being prepared at present by the Society for Space Research).:

- number of channels per satellite
- reliability of the satellites
- satellite lifetime
- satellite development costs
- production costs of the satellites
- reliability of the booster system
- costs of the booster system
- investment in ground systems
- home receiver systems
- time of starting operation of the system
- annual operating costs

Here we shall undertake only a qualitative comparison of costs between a cable system and a satellite system for television transmission (Figure 9). This shows that the cable system is superior to the satellite system for centers of population (low percentage number of viewers). On consideration of thinly settled areas and high percentages of viewers, television transmission via satellites becomes less expensive than a pure cable system. It might be possible to optimize the system by combining the television transmitting satellites with cable systems and, if necessary, with local ground transmitters.

/12

8. Summary

The German Federal Post Office requirements for an additional need for television programs in the forseeable future can be met by a satellite system for television broadcasting. Particularly in combination with local cable systems, this system is an attractive, relatively economical solution for broadcasting, with which almost every viewer in the covered area can be reached directly.

There is still a series of technological and systems-technology problems. For their solution, a directed pre-development program and a test program with a preliminary test satellite are recommended.

Construction of an operational satellite system for television broacasting could be completed by the beginning of the 1980's.

REFERENCES

1. "Konzeptstudie für einen Fernsehrundfunksatelliten," [Conceptual Study for a Television Transmitting Satellite (preliminary phase A)]. Siemens AG., Standard Electrik Lorenz, Messerschmitt-Bölkow-Blohm GmbH. May 1972.

2. "Konzeptstudie Fernsehrundfunksatellit," [Conceptual Study for a Television Transmitting Satellite (preliminary phase A)]. AEG-Telefunken, Dornier System, ERNO-Raumfahrttechnik GmbH. May 1972.

3. TRW-Systems-Group, Television Broadcast Satellite Study. October 1969.

4. NASA, Phased Project Planning Guidelines, 1968.

The author thanks Mr. Fromm, Dr. Mecke, and Mr. Schacks for their kind assistance in production of the manuscript.

3

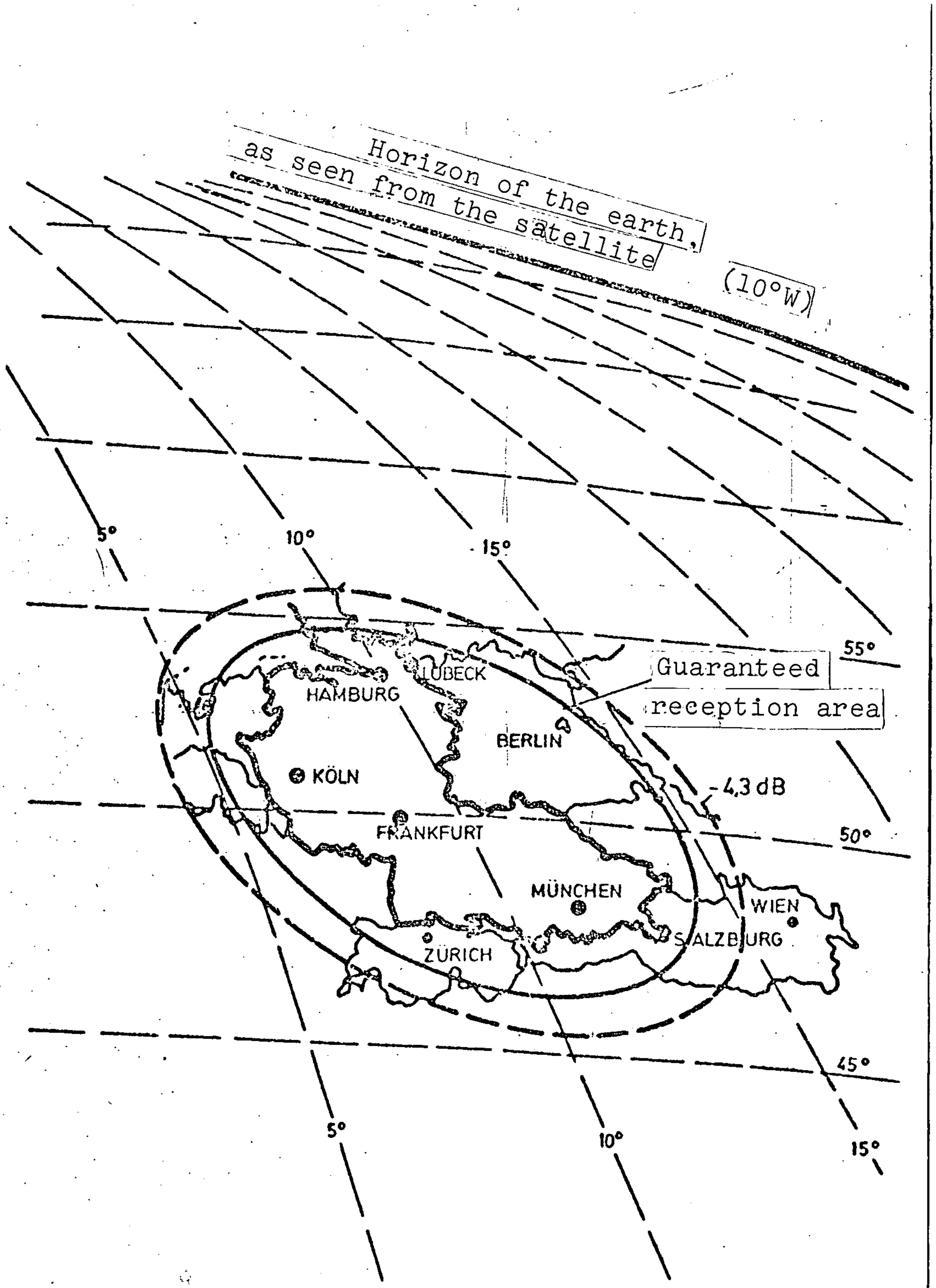

Figure 1. Coverage area, considering an attitude error of 0.1°.

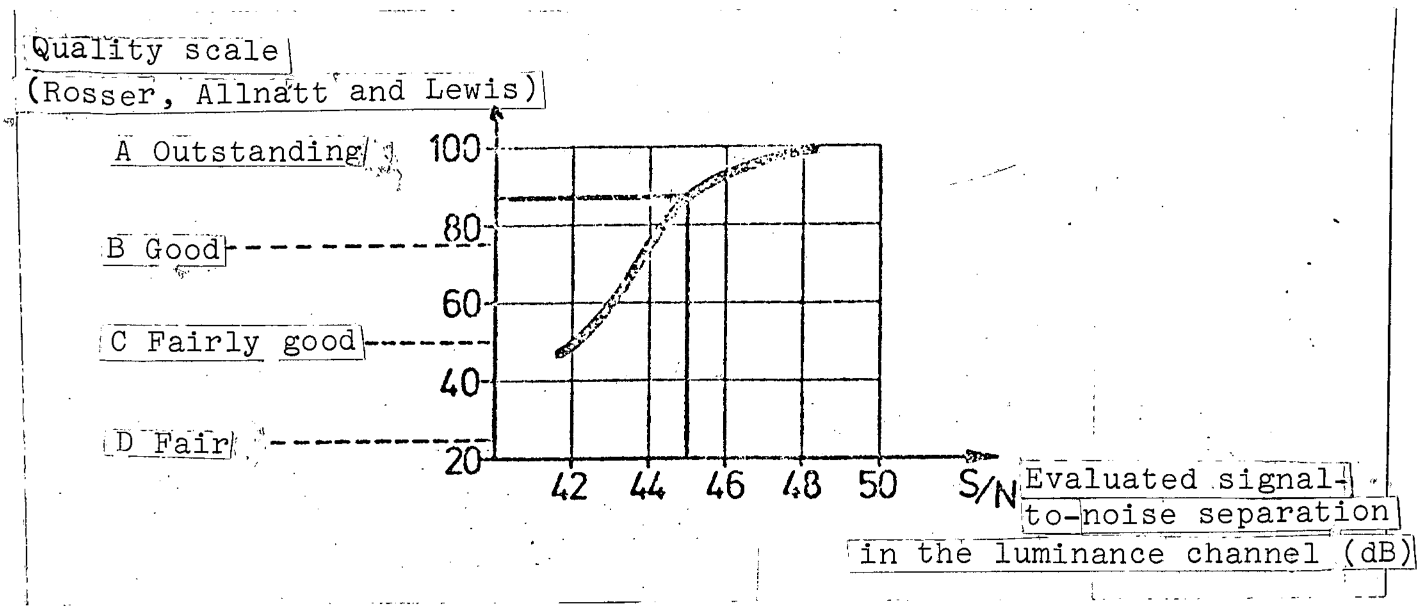

Figure 2. Quality evaluation of a television picture disturbed by noise.

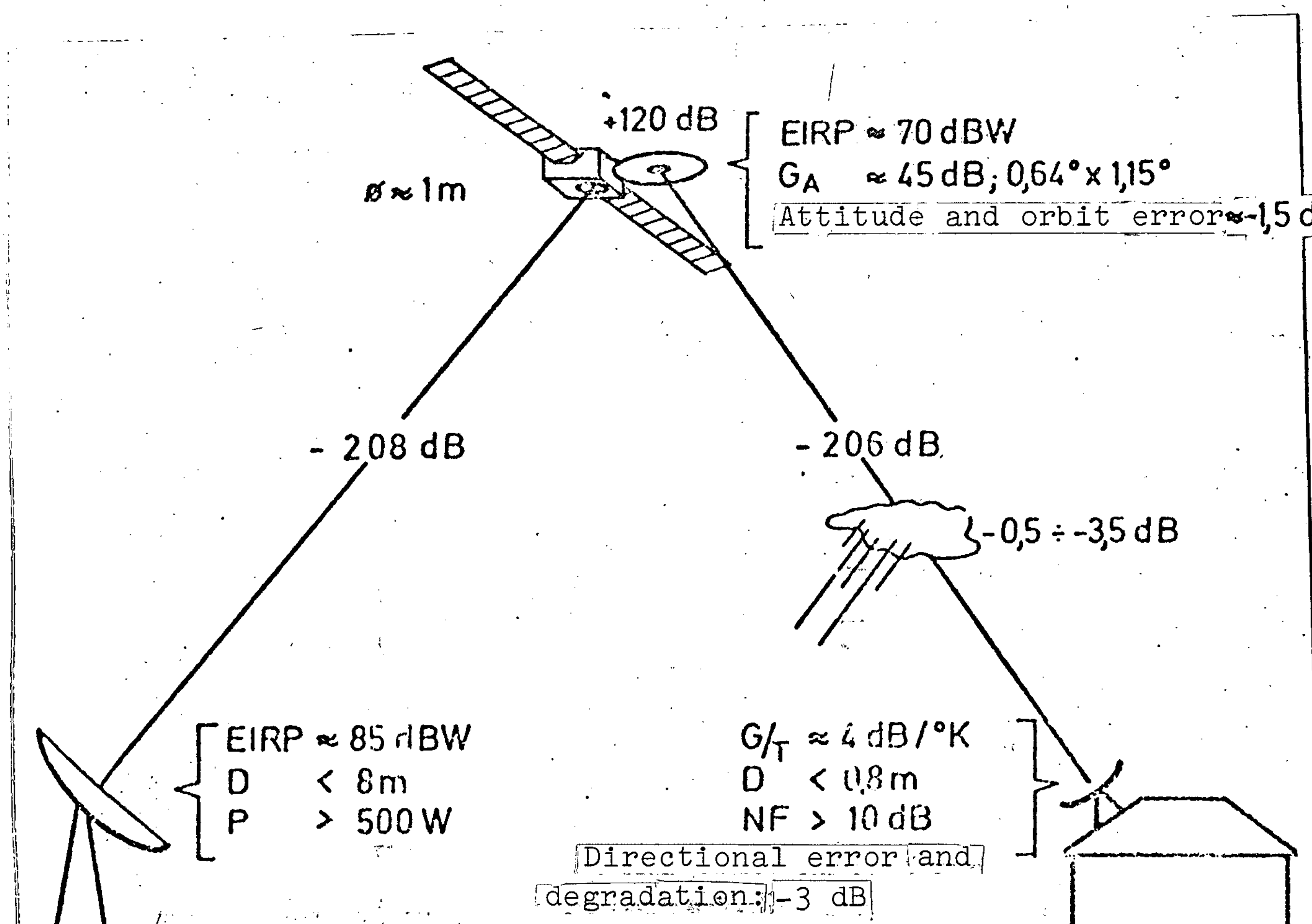

Figure 3. Communications technology system.

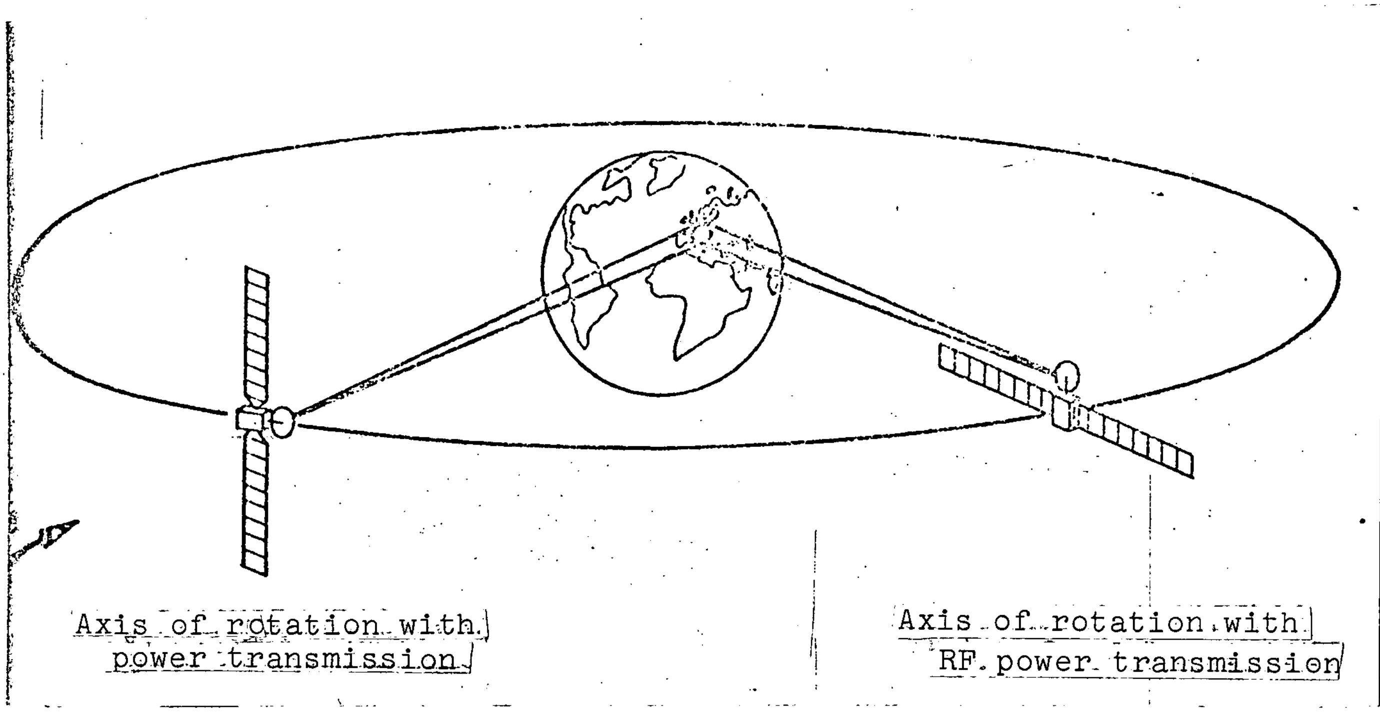

Figure 4. Basic concepts for a television transmitting satellite.

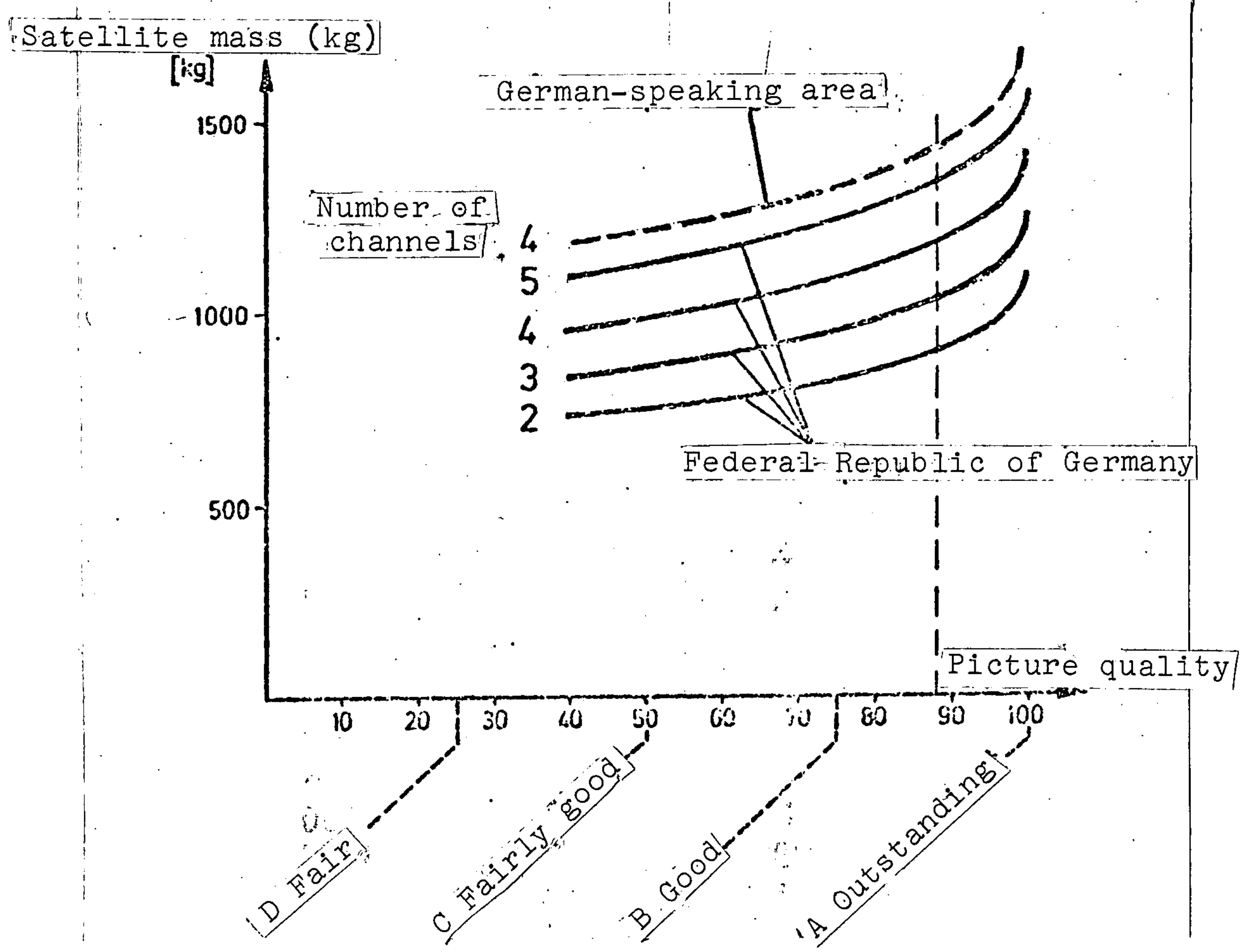

Figure 5. Dependence of satellite mass on the picture quality.

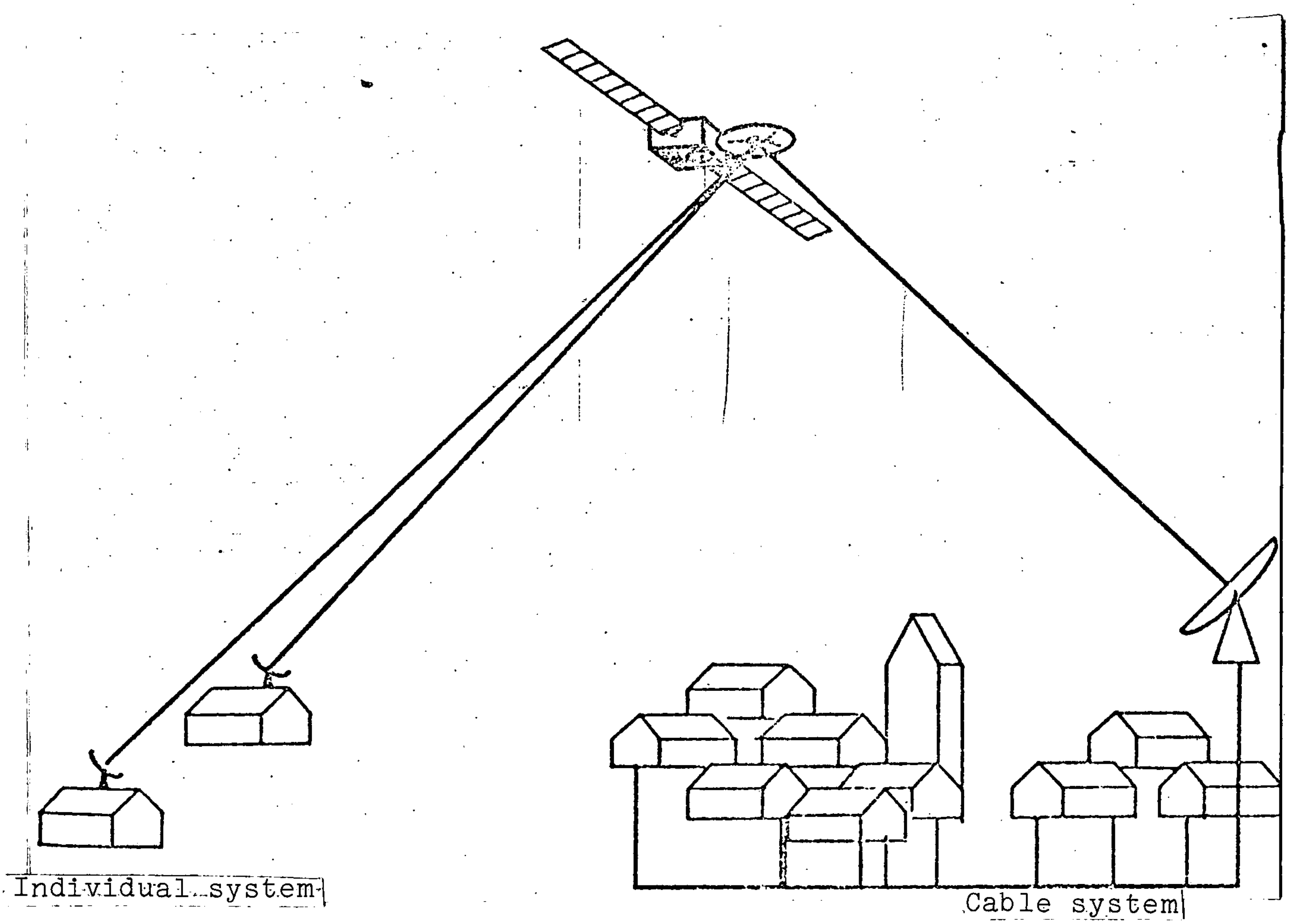

Figure 6. Home receiver system.

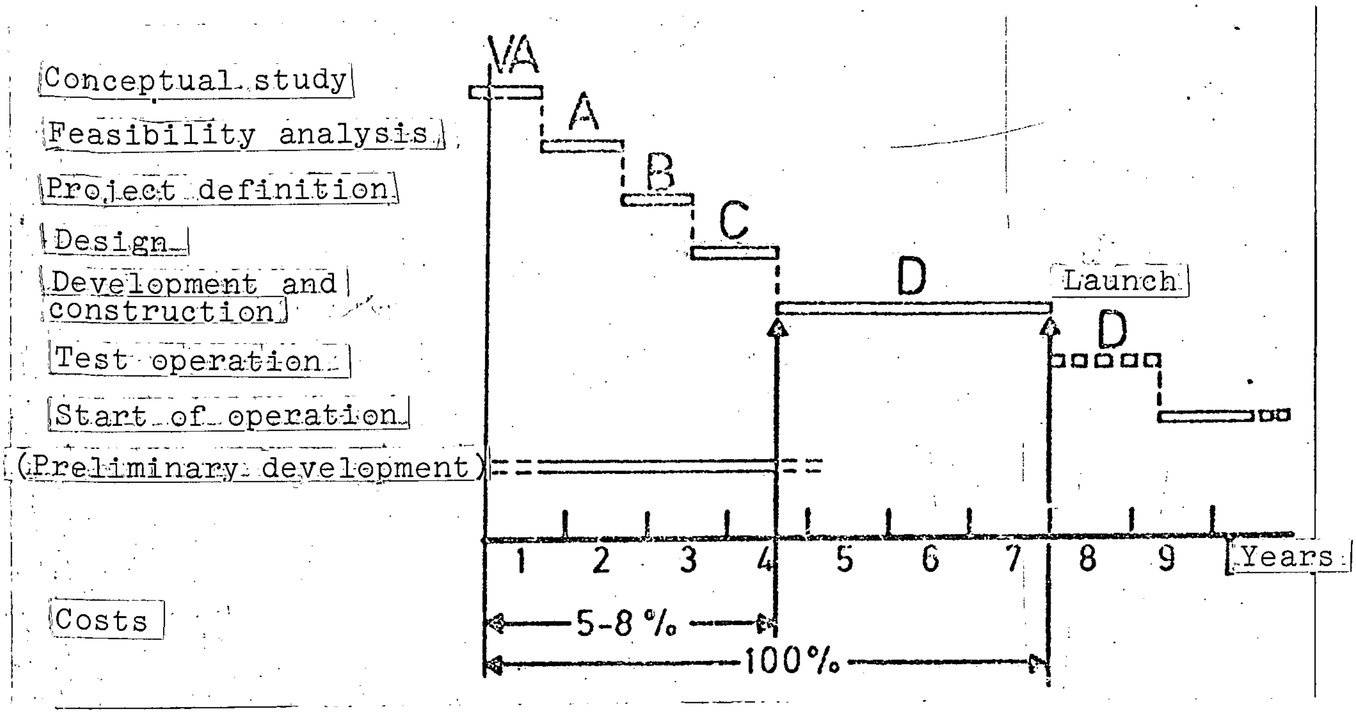

Figure 7. Television transmission satellite. Phasewise project planning without a test device.

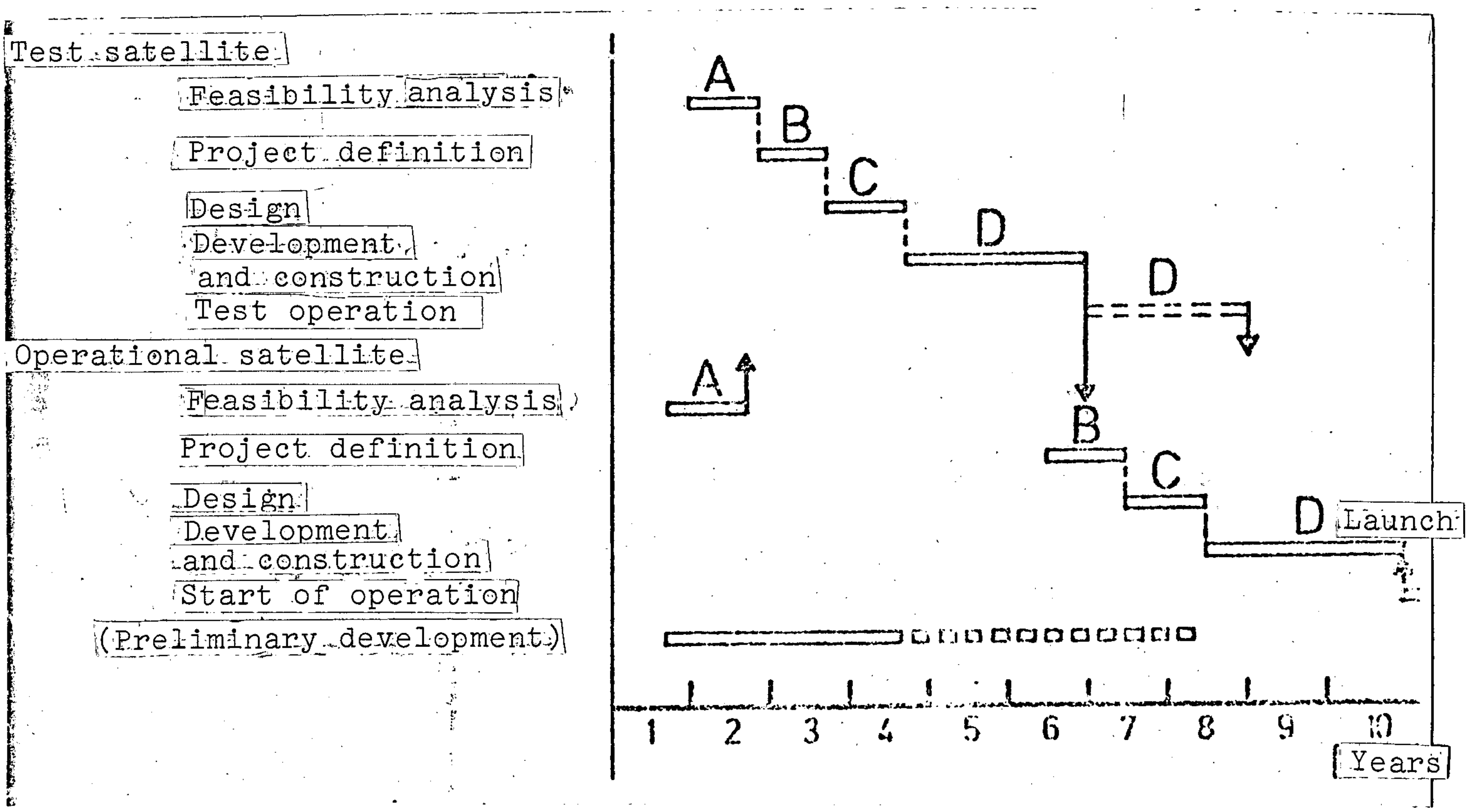

Figure 8. Television transmission satellite. Phasewise project planning with a test device.

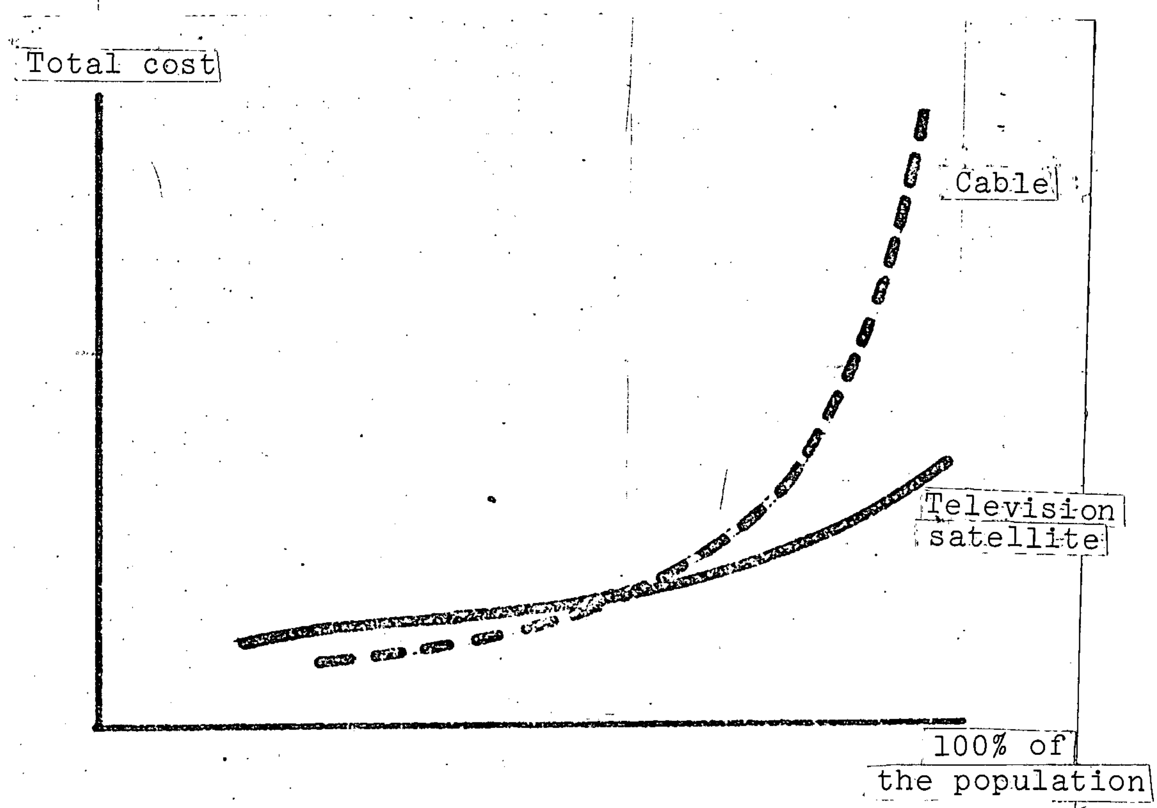

Figure 9. Crude cost comparison between a cable system and a television transmitting satellite.